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AIR MATERIEL COMMAND, ENGINEERING DIV., DAYTON, O.
(SERIAL NO. MCREXD-694-17A)

PSYCHOLOGICAL FACTORS IN CHECK READING OF SINGLE INSTRUMENT - AND APPENDIX I - MEMORANDUM REPORT

WALTER F. GRETHER; SHIRLEY C. CONNELL 20 SEPT '49 21PP
PHOTOS, TABLES

AMC, WRIGHT-PATTERSON AIR FORCE BASE, DAYTON, O.

AIRCRAFT INSTRUMENTS (9)
GENERAL (0)

INSTRUMENTS - DESIGN PSYCHOLOGY
INSTRUMENTS - READING ERRORS

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ENGINEERING DIVISION

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MEMORANDUM REPORT ON

Date: 20 September 1948

SUBJECT: Psychological Factors in Check Reading of Single Instruments

SECTION: Aero Medical Laboratory

SERIAL NO.: MCREXD-694-17A

Expenditure Order No. 694-27

A. PURPOSE:

1. This study was conducted to compare the suitability of five different principles of instrument indication for check reading purposes. Two types of reading evaluation were made: (a) simple check reading, or the mere detection of a deviation and (b) qualitative reading, or judgement of the direction of a deviation.

B. FACTUAL DATA:

2. In this experiment, the exact quantitative information presented on a standard airspeed indicator was duplicated on four other simulated instruments, all of which were then compared for ease of check reading. A rotating dial, a rotating pointer, a moving pointer on a linear scale, a moving linear scale and a direct reading counter were the indicators used. These instruments are shown in Figure 1 of Appendix I.

3. Three separate experiments were undertaken. In each, the task of the subject was to respond by appropriate movement of a toggle switch to random presentations of the five simulated instruments in an exposure apparatus. This apparatus consisted of a panel with a window behind which the instrument assemblies could be interchangeably mounted. A shutter covered the indicator between trials. In one of the experiments the subject was required to judge whether or not the instrument reading had changed from a desired reading (check reading). The other two experiments required the additional judgement of the direction of deviating readings (qualitative reading).

4. The results of these experiments showed that the time for simple check reading and making of an appropriate switch movement ranged from 0.51 seconds for a rotating pointer to 0.64 seconds for a rotating dial indicator. For the more complex qualitative reading the response times ranged from 0.59 to 1.09 seconds with considerable variation depending upon the type of indicator and direction of switch movement. In general the moving pointer indicators were superior to those with moving scales. For both types of reading which were measured the direct reading counter with three digits gave results comparable to the best indicators.

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C. CONCLUSIONS:

5. The following conclusions are drawn from this series of experiments:

a. Moving pointer instruments are in general superior to moving scale instruments for ease of check and qualitative reading.

b. For judging the direction of an instrument deviation in terms of increase or decrease the 9 and 12 o'clock positions of a circular dial are somewhat superior to the 3 and 6 o'clock positions.

c. A moving pointer on a circular dial appears to be slightly superior to a moving pointer on a linear scale for ease of check reading. For qualitative reading the moving pointer on a linear scale appears to have a general advantage over a rotating pointer since the former has the same direction of motion for all parts of the scale.

d. A direct reading counter with only three digits gives excellent results for ease of check and qualitative reading when only one instrument is being read as in this investigation.

e. In measurements of qualitative reading, which involve judging the direction of a deviation, the nature of the response required of the subject is a significant factor in determining the speed and accuracy of response.

D. RECOMMENDATIONS:

6. None.

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APPENDIX I

Psychological Factors in Check Reading of Single Instruments

Introduction

In a large number of situations, including that of the aircraft cockpit, it is necessary that instruments and indicators be check read with the greates possible accuracy and speed. At certain times, as for instance, when the plan is at cruising speed, the airspeed indicator is read in this manner. That is, it is merely "checked" to determine whether or not a change of the indicator from the normal or null position has occurred. This restricted type of reading function has been defined in a report by Grether (2) in which he differentiates it operationally from qualitative instrument reading which determines the meaning of a deviation from the normal or null position, and quantitative instrument reading which determines the actual numerical value of an indication. This study is one in a series of experiments undertaken by the Psychology Branch of the Aero Medical Laboratory in order to establish some of the psychological specifications for optimum check reading and qualitative reading efficiency.

One important question with regard to check reading of single instruments is the extent to which speed and accuracy of reading is a function of the type of display principle used. The purpose of the investigation was, therefore, to compare several widely differing means of presenting quantitative information over a wide range of values with regard to their respective merits for check and qualitative reading purposes. Underlying the study was the assumption that the nature of most check reading errors is such that it should be possible to eliminate many of them by proper design of instruments. An illustration of the improvements in ease of check reading from changes in instrument design is found in a report by Warrick and Grether (6) of studies of the design of engine instrument panels. Their investigations showed that a group of sixteen simulated engine instruments with horizontal pointer alignment could be check read in approximately 0.75 seconds. A study of altimeter design by Grether (1) has shown that relatively great differences in speed and accuracy of quantitative reading can result from differences in instrument design. It is believed that most of the instrument reading carried out by pilots is in the nature of check reading and qualitative reading rather than the slower and more complex quantitative reading. This belief is supported by a study of pilots' eye movements during instrument flight (3), which showed that for most instruments the average fixation time is about 0.5 seconds, which could scarcely permit reading the actual numerical value being indicated.

The exact quantitative data chosen for experimental variation in this investigation was that of the standard airspeed indicator. Five commonly encountered principles of display were employed in instruments to be compared both under simple check reading and qualitative reading conditions. A third comparison was made to evaluate some of the factors influencing performance on the standard rotating pointer instrument.

In carrying out this investigation three seperate experiments were conducted as follows:

Experiment I. Qualitative Reading Evaluation of Five Different Principles of Indication.

Experiment II. Simple Check Reading Evaluation of Five Different Principles of Indication.

xperiment III. Qualitative Reading of Rotating Pointer and Rotating Dial Instruments in Relation to Pointer Position and Nature of Response.

Experiment No. 1. Qualitative Reading Evaluation of Five Different Principles of Indication.

Purpose.

The purpose of Experiment No. 1 was to compare the speed and accuracy of qualitative reading for five principles of indication; a rotating pointer, a rotating dial, a moving pointer on a linear scale, a moving linear scale, and a direct reading counter. Qualitative reading was measured by requiring the subjects to indicate by an appropriate switch movement whether a presented instrument reading was higher, lower, or the same as a desired and previously observed instrument reading.

Apparatus, Procedure and Subjects.

Figure 1 (page 16) contains photographs of the five simulated airspeed indicator designs used in this experiment along with some of the results. These instruments all presented essentially the same information in widely differing fashions.

As seen in Figure 1, the five simulated instruments ranged from a direct reading counter (E) to a conventional airspeed indicator (A). This latter design used a single pointer to indicate airspeed on a 50- to 700-mile scale with graduations at every 10 miles, intermediate graduations at every 50 miles, and numerals at every 100 miles. As with the other instruments of this study, scale intervals were of equal size throughout the range of indication.

Instrument B of Figure 1 somewhat resembled certain directional indicators; the pointer was permanently fixed at the 9 o'clock position, and the dial moved behind the pointer. The pointer and a 120° arc of the rotating dial were exposed behind a window.

Instrument C of Figure 1, a linear scale with a moving pointer, was a linear counterpart of the circular dial (A) with a moving pointer. Instrument D, a moving linear scale behind a fixed pointer, bore the same relationship to the circular dial B.

The direct reading counter (E of Figure 1) has in somewhat similar studies on altitude indicator designs (see reference 1) been demonstrated to require a minimum amount of interpretation for quantitative reading but is thought to be lacking in certain valuable cues provided by changes in scale and pointer relationships. In this case, three columns of digits were used to provide comparability to the other experimental instruments.

The testing equipment may be described briefly as follows: in the center of an 18-inch by 24-inch black bakelite panel was cut a 3 1/2-inch square window before which a shutter-like shade of the same material was lowered. The simulated instruments were installed directly behind the window in a framework constructed in such a way that the five instrument assemblies could be interchanged and shown separately in an irregular sequence. The instrument was exposed by raising the shade with controls in the rear of the panel. The opening of the shade started a clock which was stopped by the subject when the correct response was made. Upon completion of the response, the shade was again lowered, permitting the experimenter to adjust the instrument for the next trial. By means of measurements made with the Macbeth Illuminometer, the intensity of illumination on the surface of the instruments was adjusted to approximately 30 foot lamberts for the white markings on the instrument faces.

The subject held in his lap a three-way toggle switch for registering his responses. According to the instructions given him the subject was to push the switch handle upward if the instrument reading had increased beyond a desired and previously presented reading, to the right if it had not changed, and downward if it had decreased. The clock for timing continued running until the correct switch movement was made. In case of error the subject always corrected his response before the screen was lowered in preparation for the next trial.

During a typical test session the subject was seated before the apparatus, eyes level with and 28 inches from the display panel. After appropriate instructions the subject was given a few practice trials to acquaint him with the procedure. Following a ready signal from the administrator, the shade was raised to reveal one of the instruments. The subject was required to note and remember the setting which was shown so that he could detect deviations from it on subsequent exposures. A series of eight trials then followed to which the subject responded by manipulation of the switch to indicate whether or not deviations from the setting had occurred. Because of parallax and slight irregularities in the pointer alignment the subject was instructed to disregard deviations from the original setting of less than one graduation or 10 miles, though actually no deviations of less than 20 miles were presented. Three successive settings with eight trials each were presented for each of the five instruments. Both time and error scores were recorded by the administrator.

The order of presentation of instruments and instrument settings was systematically varied to balance out practice and fatigue effects, as well as any remaining warm-up effects. With 20 subjects used in each comparison there was a total of 160 judgements for each setting and 480 judgements for each instrument. Settings of 150, 210 and 300 miles per hour were used on all instruments with the exception of the dial with rotating pointer on which 150, 210 and 500 miles per hour were presented. The 500 mile per hour reading was included so that settings from both the right and left halves of the dial would be presented. These figures represent minor, intermediate, and major scale divisions but were otherwise arbitrarily chosen.

The cruicial difference between this and the experiment which follows lies in the nature of the subject's response. In the present instance, not only deviations from the original setting but also the direction of deviation was noted. Thus, if the instrument on a particular trial or exposure indicated an airspeed which was in excess of the original setting, the subject's response indicated not only that the reading was different but that it was greater than the original. This type of interpretation is called "qualitative" reading to distinguish it from simple check reading where only the presence or absence of deviations is considered.

Twenty male subjects from the Aero Medical Laboratory were used as subjects, five of whom were qualified pilots with 600 or more hours flying experience. From examination of the data, it appears that experience of these latter subjects in using the standard airspeed indicator did not have a significant effect upon the results.

Results.

The major results are shown in Table I and Figure 1 in terms of the average response time and the frequency of errors for each of the five indicators. It will be noted that the response times range from 0.61 to 0.90 seconds, and that the errors range from 6.3 to 32.8 per cent of total responses for the five indicators.

One of the most striking findings shown by these data from Experiment No. 1 is the rather great difference in speed and accuracy of qualitative reading for the right and left halves of the standard dial with a rotating pointer. In fact, for both speed and errors the performance on the remaining four indicators fell between the two extremes obtained on the two halves of the standard dial. That the right side of a circular dial is actually as unfavorable as the results would suggest can be questioned because of the nature of the switch response which was required of the subject. On the right side of the dial an increase was indicated by a downward deviation of the pointer, to which an opposite (upward) movement of a toggle switch was required of the subject. In contrast, on the left half of the dial an increase was indicated by an upward pointer movement requiring also an upward movement of the toggle switch. The results of Experiment No. 3 showed that this direction of switch in relation to indicator motion can have a considerable effect upon the results.

Among the remaining indicators none of the differences were very great, although in general the indicators with moving scales and stationary pointers were inferior in terms of speed of response to those with moving pointers. The direct reading counter gave very satisfactory results, being read only slightly less rapidly than the best moving pointer indicators.

Experiment No. 2. Simple Check Reading Evaluation of Five Different Principles of Indication.

Purpose.

The purpose of Experiment No. 2 was to compare the speed and accuracy of simple check reading for five principles of indication: a rotating pointer, a rotating dial, a moving pointer on a linear scale, a moving linear scale, and a direct reading counter. For this purpose the subject was required to indicate by an appropriate switch movement whether a presented instrument reading was the same or different from a desired and previously observed reading.

Apparatus, Procedure and Subjects.

The same apparatus was used as in the first experiment although the testing procedure was somewhat modified to suit the different purpose. Only two of the response switch positions were used and the subject was require to move the switch arm to the left if the presented reading was the same and to the right if different from the desired and previously presented reading. As in the previous experiment three settings (150, 210 and 300 miles per hour) were used on each instrument and eight trials were presented at each setting. An exception was made for the rotating pointer indicator for which four settings (150, 210, 500 and 610 miles per hour) were used in order to have two settings on the left as well as the right half of the dial. It is emphasized that the major change in the second experiment was that the subject was required only to judge whether or not a change had occurred since the last reading. A decision as to whether the reading had increased or decreased was not involved, as it was in Experiment No. 1. Extensive counterbalancing procedures controlled practice, fatigue and learning effects.

Twenty male subjects were again used, 16 of whom had also served in the preceding experiment. Approximately three weeks intervened between the two experiments.

Results.

The results of this experiment are summarized in Table I and Figure 2. It is evident that simplification of the task in Experiment No. 2 resulted in more rapid response time than was obtained from the more complex qualitative reading in Experiment No. 1. Moreover the differences between indicators were considerably smaller for simple check reading.

In comparing the results for the different indicators in Experiment No. 2 it is noted that the difference between the right and left half of the standard dial was considerably reduced, presumably because in simple check reading the direction of deviation is not a factor in the response. In agreement with the first experiment the fixed pointer instruments, B and D, gave somewhat poorer results. Apparently displacement of a pointer is easier to detect and respond to than displacement of a scale. For the type of reading required in this experiment the direct reading counter, E, was approximately equal to the moving pointer indicators, A and C.

Although the difference between response times for the best and poorest indicators in this experiment is rather small (0.51 versus 0.64 seconds) it can be assumed that the actual advantage of the best over the poorest indicator is greater than this difference would suggest. It must be remembered that this response time measures a combination of perceptual time and motor time. The purely motor time was presumably a constant for all five of the indicators. If the perceptual time could be separated from the motor time and the differences expressed as per cent increase in perceptual time, the relative merits of the various indicators would become more evident.

Experiment No. 3. Qualitative Reading of Rotating Pointer and Rotating Dial Instruments in Relation to Pointer Position and Nature of Response.

Purpose.

Experiment No. 3 was conducted in order to broaden and extend some of the findings of the two previous investigations. From the first two studies, it was evident that an indicator incorporating a moving pointer on a fixed dial is superior to a fixed pointer on a moving dial. It also appeared that the efficacy of qualitative reading of the rotating pointer instrument might be a function of the sector of the dial from which readings are being made and that this is probably related to the type of response motion. In this third experiment only the rotating pointer and rotating dial indicators were studied with special reference to the dial quadrant and the direction of response switch motion being used.

Apparatus, Procedure and Subjects.

The apparatus and experimental procedure of this study follow that of Experiment No. 1 in outline but differ in several important respects. Though only the two circular indicators were used (rotating pointer and rotating dial), eight different evaluations were made since each of the four quadrants of each dial was considered as a separate instrument. The instruments were mounted in the same exposure apparatus and recording and administration were the same as in Experiment No. 1. However, instead of being required to remember from trial to trial what the correct setting should be, the subject had directly opposite him on the left a reference dial with the correct setting to which he could refer at any time.

In this study the subjects were divided into four groups in accordance with the four principle ways in which a switch might be moved in response to a dial reading which was too high (that is, up, down, left or right). Each subject was tested on all quadrants of both instruments so that for each group of five subjects, the motion of the response switch and of the pointer (or dial face) was in agreement in one quadrant, in direct disagreement in the opposite quadrant, and presumably unrelated in the two remaining quadrants. As before, settings of 150, 210 and 300 were used on all instruments, but an equal number of settings at 480, 500 and 550 were also included in the event that scores might be appreciably influenced by the size of the numerical readings. Extensive counterbalancing procedures controlled practice, fatigue and learning effects.

As in the previous experiments, 20 male members of the Aero Medical Laboratory staff were used as subjects, 13 of whom had served in both former studies and 3 of whom had served in only one, the remainder being used for the first time.

Results.

The results of Experiment No. 3 are summarized in Table II which gives response times and Table III which gives errors. In both tables the results are broken down according to subject groups, each group having a different response switch motion for signalling increase and decrease from the desired reading. The underlined values in the tables are for the dial quadrants in which the switch motion was in the same direction as the pointer deviation for the rotating pointer indicators. For the rotating dial indicators the underlined values have the same meaning, except that there was actually no pointer movement. Rather the dial moved behind the pointer in the opposite direction. For this latter case, therefore, the underlined values indicate dial motion in a direction opposite to that of the required response switch motion. At the bottom of Tables II and III are the combined data for all groups on the eight types of indicators.

In all instances the results favored the rotating pointer over the rotating dial. As might have been expected, performance on any quadrant of the rotating pointer instrument when switch and pointer movement coincided was very substantially superior to performance on the same or opposite quadrant when switch and pointer movement disagreed. In cases where the switch and pointer movements were independent or in opposite planes, performance was generally poorer than for quadrants where movements coincided and quadrants where movements disagreed. This is a reflection of the fact that subjects may sometimes improve their scores with reverse motion relationships by orienting themselves to correct for the change in the pointer or dial position rather than to follow the pointer movement. Certainly it is clear that in general responses tended to follow indicator movement and that performance on any instrument was closely related to the mode of response.

No evidence was amassed which would indicate unequivocally the superiority of any one dial quadrant over any other. General tendencies for shorter time and fewer errors in the 9 and 12 o'clock areas support the results of a related study by Warrick and Grether (6) on the influence of dial sector on speed and ease of check reading of groups of instruments. In this study an entire panel of 16 rotating pointer instruments was check read by the subject with the pointers aligned at the 3, 9 or 12 o'clock positions.

Summary and Interpretation of Results of Three Experiments

Several general findings with regard to ease of check and qualitative reading are revealed by the results of the three studies. In all cases a moving dial or scale behind a fixed pointer resulted in somewhat poorer performance, particularly in terms of speed of response. There was also some tendency to make more incorrect responses on this type of indicator. This general finding indicates that displacement of a scale is more difficult to detect and interpret than a comparable displacement of a pointer. The reason for this is probably that check reading of the scale requires reading of one or more of the numerals on the scale. On a moving pointer indicator a mere shift in position of the pointer is a sufficient cue and the numerals on the scale need not be read. On a rotating pointer indicator there is not only a displacement of the pointer tip but also a change in the angular position of the pointer. For this reason, probably, the rotating pointer with comparable direction of motion appeared to be slightly superior to a pointer moving against a linear scale.

This finding that moving scale indicators are inferior is somewhat in conflict with results obtained by Sleight (4) in favor of open window (moving scale) instruments. There are two possible explanations for this disagreement. The experiment by Sleight was concerned only with quantitative reading and used a controlled exposure interval which permitted no shift in visual fixation from that which the subject had made in advance of the exposure. It is believed that such a controlled exposure favored the open window or moving scale indicators since on these the subject knew in advance where the indication would appear.

Another finding which was clearly revealed by the present series of experiments is that the nature of the response required of the subject has a considerable effect upon the findings with regard to qualitative reading. This was especially clear in Experiment No. 3. This finding gives emphasis to the need for adequate knowledge concerning optimum relationships between indicator and control movements in aircraft. Some data on this problem are already available from experiments by Warrick (5). It is quite clear from these instances that any experiments on instrument reading which require a manual response must give adequate consideration to the role played by this response in influencing the results.

It appears quite evident from the results of this series of experiments that the most common aircraft instrument, a rotating pointer on a circular dial, is an excellent type of indication for the purposes of check reading and qualitative reading. When judgement of the direction of a deviation is required, that is for qualitative readings, the 9 and 12 o'clock positions of such a dial appear to be somewhat superior to the 3 and 6 o'clock positions. In this respect the results support the earlier findings of Warrick and Grether (6) on check reading of groups of engine instruments.

Another noteworthy finding of this investigation is that a direct reading counter with only three digits is very easily check read, being among the best of the indicators studied. Judging the direction of the deviation, that is qualitative reading, was also quite easy with this indicator. It is believed, however, that further studies should be made before it can be safely concluded that direct reading counters should be put into general use as aircraft instruments. It is quite probable that counters with more than three digits might give quite different results. It is also possible that in instrument groups, where the reader would be required to shift from one indicator to another or check the group as a whole, the results for the direct reading counter might be less favorable.

Conclusions.

From the findings of this investigation the following conclusions can be drawn:

1. Moving pointer instruments are in general superior to moving scale instruments for ease of check and qualitative reading.

2. For judging the direction of an instrument deviation in terms of increase or decrease the 9 and 12 o'clock positions of a circular dial are somewhat superior to the 3 and 6 o'clock positions.

3. A moving pointer on a circular dial appears to be slightly superior to a moving pointer on a linear scale for ease of check reading. For qualitative reading the moving pointer on a linear scale appears to have a general advantage over a rotating pointer since the former has the same direction of motion for all parts of the scale.

4. A direct reading counter with only three digits gives excellent results for ease of check and qualitative reading when only one instrument is being read as in this investigation.

5. In measurements of qualitative reading, which involve judging the direction of a deviation, the nature of the response required of the subject is a significant factor in determining the speed and accuracy of response.

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TABLE 1

Mean Number of Seconds Per Reading and Per Cent of Readings in Error For Five Simulated Airspeed Indicators.
N = 20

Indicator	Experiment No. 1 Qualitative Reading		Experiment No. 2 Simple Check Reading	
	Mean Time (seconds)	% Error	Mean Time (seconds)	% Error
A. Dial, Rotating Pointer				
Right Side	0.90	32.8	0.55	13.8
Left Side	0.61	6.3	0.51	9.1
B. Dial, Rotating Dial	0.80	11.3	0.64	11.5
C. Scale, Moving Pointer	0.67	10.2	0.56	12.5
D. Scale, Moving Scale	0.79	12.7	0.59	13.9
E. Direct Reading Counter	0.71	9.6	0.54	10.0

TABLE II

Mean[1] Number of Seconds Per Reading and Standard Deviations of Scores on Instruments With Rotating Pointers and Rotating Dials

Experiment No. 3

Response Switch Motion for Increase:		Rotating Pointer 3 o'clock	Rotating Pointer 6 o'clock	Rotating Pointer 9 o'clock	Rotating Pointer 12 o'clock	Rotating Dial 3 o'clock	Rotating Dial 6 o'clock	Rotating Dial 9 o'clock	Rotating Dial 12 o'clock
Down	Mean (N=5)[2]	0.74	0.83	0.80	0.73	0.81	0.96	0.95	0.90
	SD	0.29	0.27	0.22	0.26	0.28	0.33	0.27	0.27
Left	Mean (N=5)[2]	0.70	0.63	0.66	0.81	0.95	0.73	0.83	0.86
	SD	0.23	0.16	0.19	0.22	0.32	0.22	0.25	0.19
Up	Mean (N=5)[2]	0.88	0.76	0.74	0.76	1.09	0.93	0.81	0.88
	SD	0.11	0.07	0.09	0.10	0.17	0.10	0.10	0.05
Right	Mean (N=5)[2]	0.72	0.77	0.71	0.59	0.81	0.93	0.86	0.73
	SD	0.10	0.10	0.21	0.19	0.12	0.09	0.13	0.10

Combined Means and Standard Deviations

	Rotating Pointer 3 o'clock	Rotating Pointer 6 o'clock	Rotating Pointer 9 o'clock	Rotating Pointer 12 o'clock	Rotating Dial 3 o'clock	Rotating Dial 6 o'clock	Rotating Dial 9 o'clock	Rotating Dial 12 o'clock
Mean (N=20)[3]	0.76	0.75	0.73	0.72	0.91	0.89	0.86	0.84
SD	0.20	0.17	0.18	0.20	0.25	0.22	0.19	0.17
Over-all Mean	0.74				0.88			
Average SD	0.18				0.19			

1 The means for seconds per reading shown here were computed from the median time per subject (based on 18 trials).

2 Underlined values are for quadrants in which switch and pointer movement agree. In the case of the rotating dial the underlined values indicate dial motion in a direction opposite to switch motion.

3 Estimated difference between means for significance at 1% confidence level is 0.11 second and at 5% confidence level is 0.08 second.

TABLE III

Per Cent Errors on Instruments with Rotating Pointers and Rotating Dials

Experiment No. 3

Response Switch Motion for Increase	Rotating Pointer				Rotating Dial			
	3 o'clock	6 o'clock	9 o'clock	12 o'clock	3 o'clock	6 o'clock	9 o'clock	12 o'clock
Down	17.8	28.9	30.0	25.5	20.0	30.0	35.6	32.2
Left	18.9	16.7	12.2	26.6	25.6	7.8	26.6	27.8
Up	22.2	15.6	11.1	15.5	25.6	24.4	8.9	16.7
Right	24.4	27.8	28.8	17.8	30.0	35.6	30.0	25.6
TOTAL	20.8	22.2	20.6	21.4	25.3	24.4	25.3	25.6
GRAND TOTAL		21.3				25.1		

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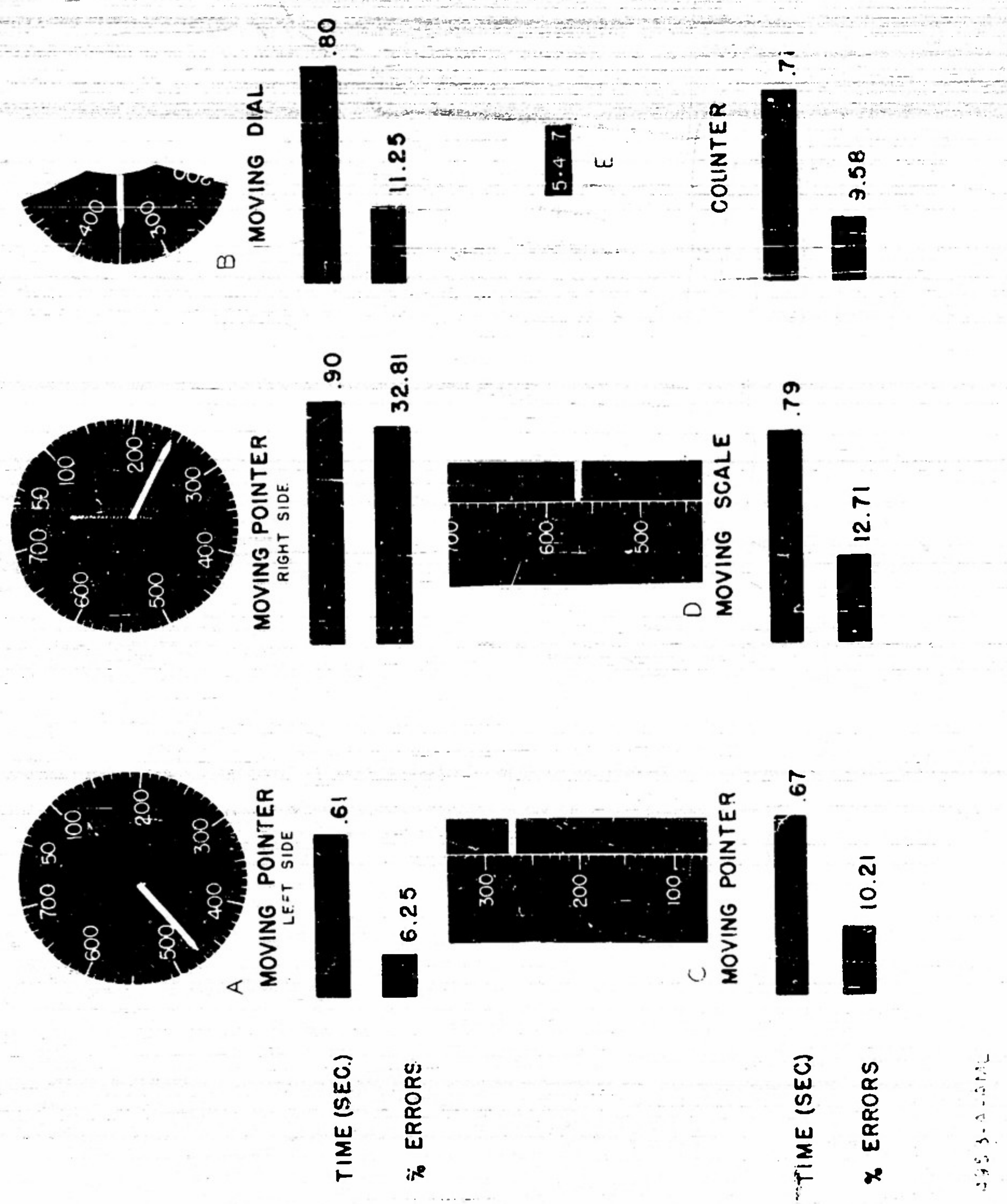

Fig. 1. Results of Experiment No. 1

Qualitative Reading of Single Instruments

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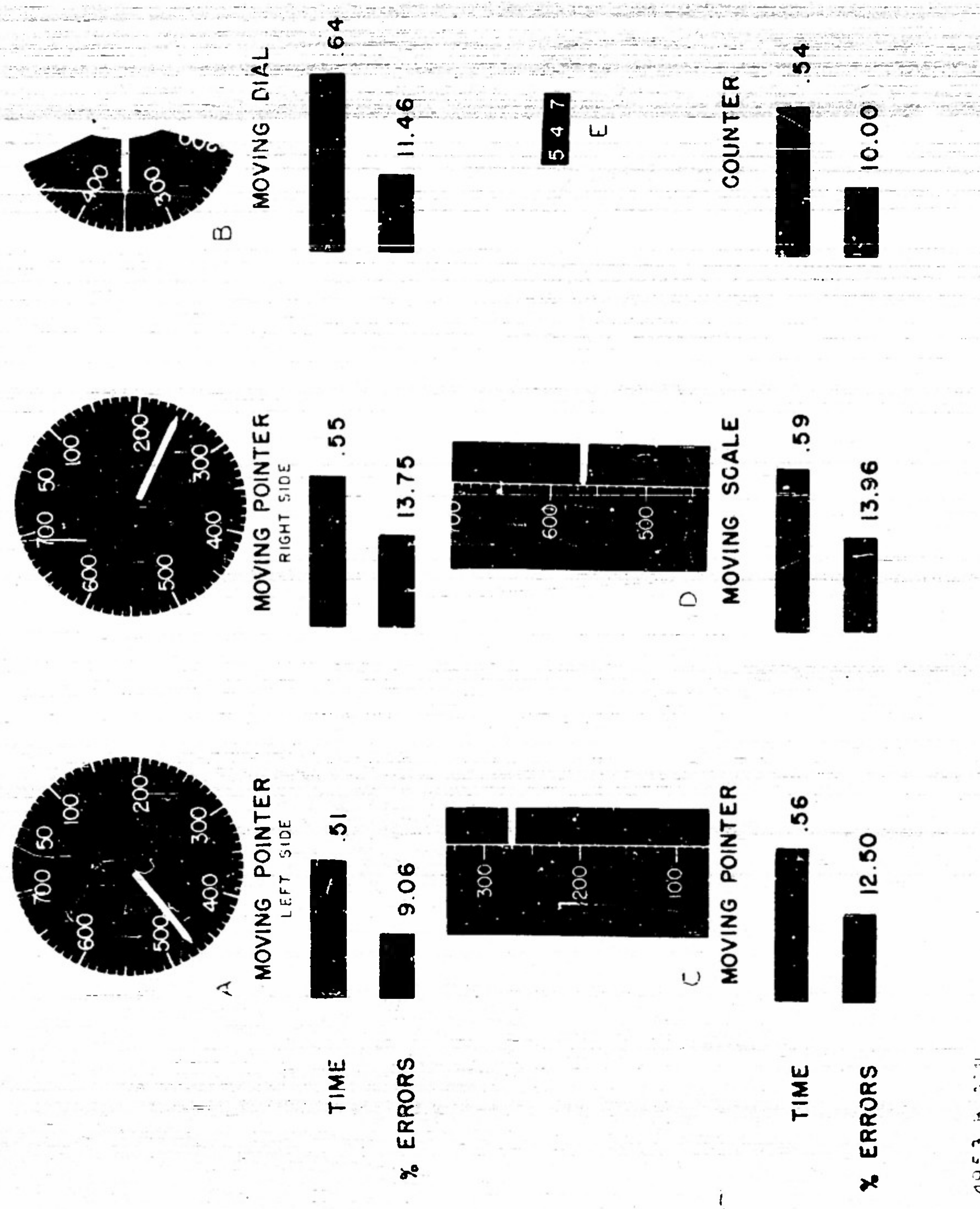

Fig. 2. Results of Experiment No. 2

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